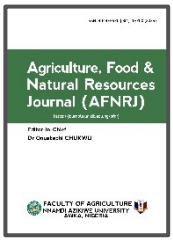
Agr. Foo. Nat. Res. J. Volume 4, Issue 2, Page 228 - 233

e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj



Original Article

Evaluation of the efficacy of *Aframomum melegueta* and *Piper guineense* for controlling *Callosobruchus maculatus* in *Vigna unguiculata*

OPEN ACCESS

MaryGeraldine Ebele OKEKE & MaryRose Ngozi EJETE

Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka, Nigeria

DOI: https://www.doi.org/10.5281/zenodo.17227496

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *April 17, 2025*
Accepted: *June 9, 2025*
Available online: *September 30, 2025*

Peer-review: *Externally peer-reviewed*

Copyright: © 2025 Author(s)
This is an open access article licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/) which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Conflict of Interest: *The authors have no conflicts of interest to declare*

Financial Disclosure: *The authors declared that this study has received no financial support.*

ABSTRACT

This study evaluates the insecticidal effects of two plant powders, Piper guineense and Aframomum melegueta, on the mortality and emergence of Callosobruchus maculatus, a significant pest of stored beans. Using a completely randomized design (CRD), different concentrations (0 g, 5 g, 10 g, 15 g, and 20 g) of the plant powders were applied to 100 g samples of black-eyed peas. Mortality rates were recorded daily for seven days. Data collected was subjected to descriptive statistics and analysis of variance. Piper guineense exhibited a remarkable insecticidal effect, achieving 100% mortality across all concentrations by Day 6. In contrast, Aframomum melegueta showed a more gradual effect, with the highest concentration (20 g) reaching only 93.33% mortality by Day 7. Additionally, P. guineense completely suppressed the emergence of adult weevils at 5 g and 15 g concentrations, while A. melegueta achieved only moderate suppression at higher concentrations. Piper guineense recorded higher average mortality at 15 g (73.33%) and 20 g (67.62%) compared to A. melegueta (57.14% and 56.67%, respectively), though these differences were not statistically significant ($p > 0.05$). Notably, P. guineense completely suppressed adult weevil emergence at some concentrations, highlighting its practical potential as a natural insecticide for managing C. maculatus in stored beans and supporting its use in sustainable pest control strategies.

KEYWORDS: *Concentrations, Emergence, Insecticidal, Mortality*

INTRODUCTION

Common bean (*Vigna unguiculata* L.), widely known as cowpea, is a vital staple crop in sub-Saharan Africa, providing a significant source of dietary protein for millions of people (Boukar *et al.,* 2016). Beyond its nutritional importance, cowpea supports the livelihoods of smallholder farmers and plays a central role in food security strategies across the region. Its adaptability to drought-prone areas and relatively low production costs makes it especially crucial for low-income households (Affognon *et al.*, 2015).

Despite its significance, cowpea production and storage face persistent challenges, among which post-harvest losses due to insect pests remain particularly severe. The cowpea weevil (*Callosobruchus maculatus*) is the most destructive pest of stored cowpea, capable of causing losses that can exceed 50% if left unmanaged (Kedia *et al.*, 2015). The pest reproduces rapidly in storage: females lay eggs on the seed coat, and emerging larvae burrow into the seeds, damaging internal tissues. This reduces seed viability for planting, lowers nutritional value for consumption, and undermines market

*Corresponding author: mna.ejete@stu.unizik.edu.ng

quality, thereby threatening household food security and farmer incomes (Affognon *et al.*, 2015).

Traditionally, farmers have relied on synthetic insecticides as the primary means of control. While effective in the short term, these chemicals raise several concerns: health risks to consumers and handlers, environmental contamination, pesticide residues on food, and the growing problem of insecticide-resistant pest populations (Stevenson *et al*., 2017). These challenges underscore an urgent need to identify and promote safer, sustainable alternatives for post-harvest pest management.

Botanical insecticides have attracted increasing attention in this regard. They are generally biodegradable, less toxic to humans and non-target organisms, and often locally available, which makes them more affordable and culturally acceptable in smallholder farming systems (Stevenson *et al*., 2017). Two such botanicals *Dennettia tripetala* and *Piper guineense* are indigenous to West Africa and traditionally used in medicine and cooking. Research suggests that *D. tripetala* contains bioactive compounds with insect-repelling and toxic properties, although its insecticidal potency may require higher concentrations for effective control (Okonkwo *et al.,* 2020). In contrast, *P. guineense* has demonstrated stronger insecticidal effects, primarily due to compounds such as piperine, which disrupt insect nervous systems and feeding behavior (Nzelu *et al.*, 2020).

However, comparative studies evaluating the effectiveness of these two botanicals under similar conditions remain limited, particularly regarding their impact on both mortality rates and suppression of adult emergence of *C. maculatus*. Understanding these differences is important for developing practical recommendations tailored to local storage practices and economic realities of smallholder farmers. Therefore, this study aims to compare the insecticidal efficacy of *Dennettia tripetala* and *Piper guineense* powders against *C. maculatus* in stored cowpea. Specifically, it evaluates their effects on adult mortality and the inhibition of F_1 adult emergence. The findings are expected to contribute to the development of sustainable, cost-effective, and environmentally friendly pest management strategies that can help safeguard cowpea grain quality, reduce economic losses, and strengthen food security in sub-Saharan Africa.

MATERIALS AND METHODS

Study Area Description

This study was carried out at the Department of Crop Science and Horticulture, Faculty of Agriculture, Nnamdi Azikiwe University, Amadi Village, Ifite Ogwari, Ayamelum Local Government Area, Anambra State, Nigeria. The study site lies within the coordinates 6.9284° N latitude and 6.8891° E longitude. It is located in the humid rainforest agro-ecological zone of southeastern Nigeria. The area experiences an annual rainfall ranging from 1,800 to 2,200 mm, with a distinct rainy season between April and October. The average annual temperature ranges from 25°C to 30°C, and the relative humidity is generally high, between 70% and 85%. (NIMET 2022)

Experimental Design

A 2 × 5 factorial experiment was laid out in a Completely Randomized Design (CRD), involving two insecticidal plant powders (*Piper guineense* and *Aframomum melegueta*) each tested at five concentration levels: 0 g (control), 5 g, 10 g, 15 g, and 20 g per 200 g of cowpea grains. Each treatment was replicated three times.

The rationale for selecting these concentration levels is based on two key considerations. First, previous studies evaluating the insecticidal efficacy of botanical powders against *Callosobruchus maculatus* have shown that doses within the range of approximately 5–20 g per 100–500 g of grains can effectively reduce adult mortality and suppress F_1 progeny emergence, while still being economically feasible and safe for smallholder farmers (Nzelu *et al*., 2020; Adesina & Ofuya, 2015). Second, testing a gradient of doses from low (5 g) to higher concentrations (20 g) allows for determining both the minimum effective dose and whether increasing dosage proportionally enhances efficacy. This helps identify an optimal rate that balances pest control effectiveness with cost and practical application in typical smallholder storage conditions.

Sourcing and Preparation of the plant extracts

Two kilograms of black-eyed peas (*Vigna unguiculata*) were purchased from Eke Awka open Market in Anambra State. Beans were sorted for uniformity, inspected for infestation, and refrigerated at 8°C for seven days to eliminate hidden pests. Seeds of *Piper guineense* and *Aframomum melegueta* were sourced from Eke Awka Market and authenticated by Experts from the department of Botany. One kilogram of each was cleaned, air-dried for 24 hours, and ground into fine powder using a nut grinder. Processing took place at the Botany laboratory, Nnamdi Azikiwe University.

Insect Source and Rearing

Adult *C. maculatus* were obtained from naturally infested cowpea grains sourced from a local market in Awka , Anambra State Nigeria. The insects were cultured under laboratory conditions (27 ± 2°C temperature and 70 ± 5% relative humidity) to establish a uniform laboratory colony. Clean, uninfested cowpea grains were sterilized by keeping them at –18°C for 7 days to eliminate any hidden infestation, then conditioned to room temperature before use. Approximately 200 unsexed adult *C. maculatus* were introduced into 1 kg of sterilized cowpea in plastic containers covered with muslin cloth to allow ventilation and prevent escape. After 10 days of oviposition, all adults were removed, and the infested grains were kept undisturbed until adult emergence. Newly emerged F_1 adults (15 days old) were then used for the bioassays.

Experiment on P. guineense and A. melegueta on C. maculatus Mortality

Each 100 g sample of sterilized cowpea grains was placed in plastic vials and treated with 0 g (control), 5 g, 10 g, 15 g, or 20 g of plant powder (*Piper guineense* or *Aframomum melegueta*). The vials were gently shaken to ensure uniform distribution of the powders over the grains.

Ten 15-day-old adults *C. maculatus* were introduced into each treated vial, and the opening was secured with muslin cloth to allow airflow while preventing insect escape. Mortalities were observed and recorded daily for seven days. Each treatment combination was replicated three times to ensure data reliability.

Experiment on the Plant Extracts on Progeny Adult Emergence

To assess emergence, 100 g of untreated beans were first infested with 10 adult weevils and kept for 14 days to allow oviposition. The adults were then removed, and the beans were treated with varying concentrations of each plant powder as above. Samples were monitored for 35 days post-treatment. Emerged adults, larvae, and pupae were counted at the end of the period. All treatments were replicated three times.

Data Analysis

Data on adult mortality and F_1 progeny emergence were subjected to one-way analysis of variance (ANOVA) using Genstat statistical software (Version 9.2). Mean differences among treatment concentrations were separated using the Least Significant Difference (LSD) test at a 5% level of significance ($P < 0.05$), (Partal & Kaşkavalcı, 2024)

RESULTS

Efficacy of Piper guineense and Aframomum melegueta on the Mortality of Callosobruchus maculatus

Table 1 presents the 7-day mortality of *C. maculatus* exposed to varying concentrations (0 g, 5 g, 10 g, 15 g, 20 g) of *P. guineense* and *A. melegueta*. Results showed significant differences ($P < 0.05$) between treatments, confirming the dose-dependent insecticidal effects of both plant extracts.

In the control (0 g), mortality was negligible, with only 3.33% observed on Day 7, indicating minimal influence from external factors. In contrast, *P. guineense* induced rapid and complete mortality across all doses. Mortality began on Day 2 at 5 g (16.67%) and reached 100% by Day 6. The 10 g and 15 g concentrations-initiated mortality on Day 1 (3.33% and 6.67%, respectively) and also reached 100% by Day 6. The 20 g treatment showed the most rapid effect, with 6.67% mortality on Day 1 and full mortality by Day 6. These results confirm the strong, consistent efficacy of *P. guineense*.

A. melegueta, however, showed a slower and less complete response. At 5 g, mortality began at 20% and rose to 70% by Day 7. The 10 g dose reached 83.33%, 15 g reached 86.67%, and 20 g peaked at 93.33% by Day 7. While *A. melegueta* demonstrated a positive dose-response, none of its treatments achieved full mortality within the 7-day period, indicating it is less effective than *P. guineense*.

Table 1: Effect of different concentrations of the plant extracts on Percentage Mortality of *C.maculatus*

Treatments Concentration(g)	Mortality						
	Day 1	Day2	Day3	Day4	Day5	Day6	Day7
P.guineense(0)	0.00	0.00	0.00	0.00	0.00	0.00	3.33
P.guineense(5)	0.00	16.67	36.67	60.00	86.67	100.00	100.00
P.guineense (10)	3.33	23.33	40.00	63.33	93.33	100.00	100.00
P.guineense (15)	6.67	26.67	60.00	86.67	93.33	100.00	100.00
P.guineense (20)	6.67	53.33	76.67	86.67	96.67	100.00	100.00
$LSD_{(0.05)}$	6.25	15.25	21.74	26.47	30.83	33.16	32.06
A.meleguetta (0)	0.00	0.00	0.00	0.00	0.00	0.00	3.33
A.meleguetta (5)	20.00	36.67	40.00	50.00	56.67	66.67	70.00
A.meleguetta (10)	23.33	36.67	43.33	56.67	66.67	66.67	83.33
A.meleguetta (15)	33.33	36.67	46.67	63.33	73.33	76.67	86.67
A.meleguetta (20)	33.33	36.67	50.00	70.00	80.00	90.00	93.33
$LSD_{(0.05)}$	11.51	13.67	16.01	21.07	24.13	26.08	27.38

Figure 1 illustrates these trends, showing a stark contrast between the treated groups and the control. The control group's mortality remained minimal (3.33% by Day 7), reinforcing the conclusion that the observed mortality in the treated groups is primarily due to the insecticidal action of the extracts. *Piper guineense* exhibited a rapid and consistent increase in mortality across all concentrations, with all treatments reaching 100% mortality by Day 6. In contrast, *Aframomum meleguetta*

displayed a more gradual mortality increase, with none of the concentrations reaching full control by Day 7.

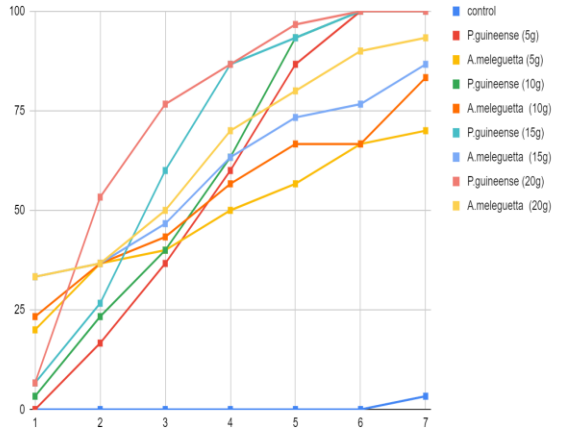


Figure 1: Mortality trends of *C. maculatus* over seven days under treatments with *P. guineense*, *A. melegueta*, and control.

Table 2: Compares the efficacy of *Piper guineense* and *Aframomum meleguetta* at varying concentrations (5g, 10g, 15g, 20g) against *Callosobruchus maculatus*. Despite the visible differences in mortality rates between the two extracts (with Piper guineense reaching 100% mortality across all concentrations), the statistical analysis shows no significant differences between the extracts at any concentration ($p > 0.05$). This suggests that while *Piper guineense* appeared to achieve complete control faster, the observed differences in mortality rates between the two extracts were not statistically significant.

Table 2: Comparing the effect of *P.guimeense and A.meleguetta* on Mortality

	Average Mortality			
Concentration	***P. guineense***	***A. meleguetta***	**p-value**	**LSD (0.05)**
5	58.10	64.76	0.71	NS
10	60.48	49.52	0.51	NS
15	73.33	57.14	0.34	NS
20	67.62	56.67	0.52	NS

Emergence of *Callosobruchus maculatus* as Affected by Different Concentrations of *Piper guineense* and *Aframomum melegueta* Extracts

Table 3 shows the emergence of *C. maculatus* under various concentrations (0 g, 5 g, 10 g, 15 g, 20 g) of *P. guineense* and *A. melegueta*. Significant differences ($P < 0.05$) were observed between treatments and control, confirming the insecticidal efficacy of the extracts. In the control (0 g), 29.33 insects emerged, highlighting the natural reproductive potential of *C. maculatus*. In contrast, *P. guineense* completely suppressed emergence at 5 g and 15 g (0 insects), while only 0.33 emerged at 10 g and 20 g, indicating near-total inhibition of progeny development at all concentrations.

A. melegueta showed a more gradual suppression. At 5 g, 7.33 insects emerged; at 10 g, emergence dropped to 2.33; and at 15 g and 20 g, it further declined to 0.33, showing strong but not total control at higher doses. Overall, *P. guineense* exhibited stronger and more consistent suppression of *C. maculatus* emergence than *A. melegueta*, which only matched its efficacy at higher concentrations. Statistical analysis confirmed the superiority of *P. guineense* in inhibiting progeny development.

Table 3: Effect of different concentration of the Plant Extracts Emergence of *Callosobruchus maculatus*

Treatment Concentration(g)	**Emergence**
P.guineense (0)	29.33
P.guineense (5)	0
P.guineense (10)	0.33
P.guineense (15)	0
P.guineense (20)	0.33
$LSD_{(0.05)}$	15.73
A.meleguetta (0)	29.33
A.meleguetta (5)	7.33
A.meleguetta (10)	2.33
A.meleguetta (15)	0.33
A.meleguetta (20)	0.33
$LSD_{(0.05)}$	15.12

Discussion

This study demonstrates the insecticidal efficacy of *Piper guineense* and *Aframomum melegueta* powders against *Callosobruchus maculatus*, a significant pest of stored cowpea. The results revealed that *P. guineense* achieved complete (100%) mortality across all tested concentrations by Day 6, highlighting its rapid knockdown effect. In contrast, *A. melegueta* attained a slightly lower maximum mortality (93.33%) at the highest concentration (20 g) by Day 7, reflecting slower but substantial activity. Although *P. guineense* recorded numerically higher average mortality rates at several dosages (e.g., 73.33% at 15 g compared to 57.14% for *A. melegueta*), statistical analysis (ANOVA) showed no significant differences between treatments at $p > 0.05$, suggesting both botanicals are comparably effective overall.

The rapid action of *P. guineense* aligns with findings by Nzelu *et al*. (2020), who attributed its quick efficacy to piperine and other alkaloids that disrupt insect neurotransmission, leading to paralysis and death. Fast knockdown is a desirable property in stored grain protection because it limits the period during which insects can feed and damage grains. Ileke *et al.* (2020) also described the neurotoxic mode of action of *P. guineense*, supporting the high mortality observed in this study.

Conversely, *A. melegueta* demonstrated a slower but progressive increase in mortality, especially at higher concentrations. This trend mirrors findings by Ekeh *et al*. (2013), who noted that the insecticidal effect of *A. melegueta* is largely due to its essential oils and phenolic compounds, which act as fumigants or antifeedants rather than immediate neurotoxins. Similarly, Adesina & Ofuya (2015) found that *A. melegueta* powders gradually increased mortality of *C. maculatus* over several days, indicating a cumulative rather than instant effect.

The minimal mortality (3.33%) observed in untreated control treatments underscores that the observed pest mortality in other treatments can be confidently attributed to the plant powders and not to natural death or handling stress. This strengthens the internal validity of the findings and reinforces the practical potential of these botanicals for storage pest control.

Importantly, the statistical similarity in overall efficacy despite different speeds of action suggests that both botanicals could serve complementary roles within pest management strategies. Nwosu *et al.* (2020) emphasized that slower-acting botanicals can still achieve effective cumulative pest suppression if properly dosed and timed, supporting the value of *A. melegueta* in storage contexts where longer-term control may be needed. Meanwhile, the rapid knockdown effect of *P. guineense* makes it particularly attractive for acute infestations where immediate pest suppression is necessary.

Parallel evidence from other commodities also strengthens the case for botanical insecticides. For instance, Ejiofor & Okonkwo (2023) evaluated the insecticidal activity of *Zingiber officinale* extract against *Prostephanus truncatus* on stored cassava chips, achieving complete mortality at higher concentrations (250 µl/ml and 500 µl/ml) after 7 days, comparable to the synthetic insecticide deltamethrin. Despite differences in target pest and crop, this study corroborates the broader effectiveness of botanicals as eco-friendly pest management options in diverse storage systems. Similarly, Ugwu *et al.*, (2021) reported high mortality using *A. melegueta* and *P. guineense* extracts against *Bactrocera dorsalis* on stored fruits, further supporting the efficacy of botanicals across different storage contexts.

The consistent efficacy observed across studies points to key advantages of botanicals over synthetic chemicals: lower environmental persistence and toxicity, reduced risk of pest resistance, and better safety for users and consumers. This aligns with Adarkwah *et al.* (2018), who highlighted botanicals as critical tools in sustainable grain storage due to their degradability and lower residue levels. Moreover, Nzelu *et al*. (2020) argued that widespread use of botanicals could mitigate health risks linked to synthetic pesticides.

It is worth noting that while *P. guineense*'s rapid action is beneficial for fast suppression, *A. melegueta*'s slower effect does not diminish its value. Rather, it may provide sustained control through prolonged deterrence and reduced pest reproduction. This supports the perspective that combining fast- and slow-acting botanicals may optimize control and delay resistance, as suggested by Nwosu *et al.* (2019).

Finally, the outcomes reinforce the principle that locally available botanicals, when appropriately processed and applied, can provide cost-effective and practical solutions for smallholder farmers facing storage pest challenges. While laboratory findings like these are promising, field validation under real storage conditions remains essential to confirm efficacy, persistence, and potential impacts on grain quality.

In summary, the present findings align well with existing literature, confirming that *P. guineense* and *A. melegueta* powders offer comparable insecticidal efficacy against *C. maculatus*, with differences mainly in speed of action. Together, they add to the growing evidence supporting botanical insecticides as viable, sustainable alternatives in the management of storage pests.

CONCLUSION AND RECOMMENDATIONS

This study highlights the potential of *Piper guineense* and *Aframomum meleguetta* as effective botanical insecticides against *Callosobruchus maculatus*, a key pest in stored legumes. Although *P. guineense* demonstrated faster and complete mortality, statistical analysis revealed no significant difference in overall efficacy between the two extracts. Both extracts significantly reduced pest populations and suppressed insect emergence, confirming their viability for pest control in stored legumes. The comparable effectiveness of *P. guineense* and *A. meleguetta* underscores the growing recognition of botanical insecticides as sustainable, safer alternatives to synthetic chemicals, reducing the risks of chemical residues while ensuring effective pest management.

Further research is recommended to explore several areas that could enhance the practical use of these botanicals. First, investigating the potential synergistic effects of combining *Piper guineense* and *Aframomum meleguetta* with other botanicals or synthetic insecticides may reveal improved efficacy against *C. maculatus*. Additionally, studies should assess the long-term impacts of these treatments on pest populations, storage quality, and the safety of stored products for consumers. Finally, it would be valuable to examine different application methods, such as incorporating these plant extracts into packaging materials or formulating essential oils, to optimize their use within integrated pest management (IPM) strategies.

Acknowledgment

I would like to express my utmost gratitude to all who supported and contributed to the completion of this article. Special gratitude goes to my able supervisor Mrs Okeke MaryGeraldine Ebele for her insightful suggestions, guidance, follow-ups and continued encouragement throughout this process. I am also grateful to my family and friends for their support and

motivation. Lastly, I appreciate each author and researchers whose work has helped enriched this study. Thank you.

Authors' Contributions

MNE performed the data collection and experimental setup. MEO supervised

Ethical Statement

This research was conducted in accordance with ethical standards. All data collection was performed with respect to privacy, confidentiality, and informed consent. The authors declare no conflicts of interest and confirm the accuracy of the data presented. All necessary permissions were obtained, and the research adheres to institutional and professional ethical guidelines.

the work and conducted the data analysis.

REFERENCES

Adarkwah, C., Obeng-Ofori, D., Prozell, S., Asante, V., Hörmann, V., & Ulrichs, C. (2018). Toxicity and protectant potential of *Piper guineense* (Piperaceae) and *Senna siamea* (Fabaceae) mixed with diatomaceous earth for the management of three major stored product beetle pests. *International Journal of Pest Management*, 64(2), 128–139. https://doi.org/10.1080/09670874.2017.1346327

Adesina, J. M., & Ofuya, T. I. (2015). Oviposition deterrent and egg hatchability suppression of *Secamone afzelii* (Schult) K. Schum leaf extract on *Callosobruchus maculatus* (Fabricius) (Coleoptera: Chrysomelidae). *Jordan Journal of Biological Sciences*, 8(2), 95–100. https://doi.org/10.12816/0027554

Affognon, H., Mutungi, C., Sanginga, P., & Borgemeister, C. (2015). Unpacking postharvest losses in sub-Saharan Africa: A meta-analysis. *World Development*, 66, 49–68. https://doi.org/10.1016/j.worlddev.2014.08.002

Boukar, O., Fatokun, C. A., Huynh, B. L., Roberts, P. A., & Close, T. J. (2016). Genomic tools in cowpea breeding programs: Status and perspectives. *Frontiers in Plant Science*, 7, 757. https://doi.org/10.3389/fpls.2016.00757

Ekeh, F. N., Onah, I. E., Atama, C. I., Ivoke, N., & Eyo, J. E. (2013). Effectiveness of botanical powders against *Callosobruchus maculatus* (Coleoptera: Bruchidae) in some stored leguminous grains under laboratory conditions. *African Journal of Biotechnology*, 12(12), 1384–1391. https://doi.org/10.4314/AJB.V12I12

Ejiofor, M. E., & Okonkwo, N. J. (2023, March). Comparative toxicity of *Zingiber officinale* and deltamethrin on *Prostephanus truncatus* (Horn). *E-Proceedings of the Faculty of Agriculture International Conference, Nnamdi Azikiwe University*, 419–422. https://journals.unizik.edu.ng/faic/article/view/1966

Ileke, K. D., Adesina, J. M., Nwosu, L. C., & Olagunju, A. (2020). Perforation index assessment of cowpea seeds against cowpea bruchid, *Callosobruchus maculatus* (Fabricius) [Coleoptera: Chrysomelidae], infestation using *Piper guineense*. *JoBAZ*, 81, 60. https://doi.org/10.1186/s41936-020-00195-7

Kedia, A., Prakash, B., Mishra, P. K., Singh, P., & Dubey, N. K. (2015). Botanicals as eco-friendly biorational alternatives of synthetic pesticides against *Callosobruchus* spp. (Coleoptera: Bruchidae)—A review. *Journal of Food Science and Technology*, 52(3), 1239–1257. https://doi.org/10.1007/s13197-013-1167-8

Nigerian Meteorological Agency [NIMET]. (2022). Climate data for southeastern Nigeria. Retrieved from https://www.nimet.gov.ng

Nwosu, L. C., Obi, O. A., Adanyi, D. D., Okereke, V. C., Azoro, V. A., Ukpai, K. U., Nzewuihe, G. U., Lawal, I. A., Uwalaka, O. A., Ugagu, G. M., Eluwa, A. N., & Arotolu, T. E. (2019). Insecticidal activities of five medicinal plant materials against *Callosobruchus maculatus* Fabricius (Coleoptera: Chrysomelidae) infesting cowpea seeds in storage. *The International Journal of Biotechnology*, 7(1), 64–69. https://doi.org/10.18488/journal.57.2018.71.64.69

Nzelu, C. O., Emeasor, K. C., & Okonkwo, N. J. (2020). Insecticidal activity of *Piper guineense* (Schumach and Thonn) seed oil against *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae) in stored cowpea seeds. *International Journal of Research - GRANTHAALAYAH*, 8(8), 262–270. https://doi.org/10.29121/granthaalayah.v8.i8.2020.875

Okonkwo, N. J., Ejiofor, M. E., Iwuagwu, C. C., Aguwa, U. O., & Ibeabuchi, U. (2020). Protectant efficacy of *Dennettia tripetala* Bak. (F) (Annonaceae) extracts and deltamethrin against *Sitophilus zeamais* Motsch (Coleoptera: Curculionidae) in stored maize. *International Journal of Research - GRANTHAALAYAH*, 8(6), 10–14. https://doi.org/10.29121/granthaalayah.v8.i6.2020.203

Partal, E., & Kaşkavalcı, G. (2024). Determination of the efficacy of some entomopathogenic nematodes on *Spodoptera littoralis* (Boisduval, 1833) (Lepidoptera: Noctuidae) in laboratory conditions. *Turkish Journal of Entomology*, 48(3), 251–259. https://doi.org/10.16970/entoted.1474895

Stevenson, P. C., Isman, M. B., & Belmain, S. R. (2017). Pesticidal plants in Africa: A global vision of new biological control products from local practice. *Industrial Crops and Products*, 110, 2–9. https://doi.org/10.1016/j.indcrop.2017.08.034

Ugwu, J. A., Alabi, O. Y., & Aluko, O. J. (2021). Insecticidal activity of crude extracts of three spices and commercial botanical pesticide on oriental fruit fly under laboratory conditions. *JoBAZ*, 82, 26. https://doi.org/10.1186/s41936-021-00227-w